PIER Buildings Program Presentation of Research

Energy Efficient and Affordable Small Commercial and Residential Buildings Research Program

ARCHITECTURAL ENERGY
CORPORATION
Integrated Engineered Solutions

pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

Program Elements

- E-1: Administration
- E-2: Automated Commissioning and Diagnostics
- E-3: Advanced Load Management & Control
- E-4: Alternative Cooling Technologies & Strategies
- E-5: Alternative Construction Techniques & Technology
- E-6: Impact Assessment

Element 2: Automated Commissioning and Diagnostics

- 2.1: Fault Detection and Diagnostics for Rooftop Air Conditioning
- 2.2: Equipment Scheduling and Cycling
- 2.3: Air Handling Unit and VAV Box Diagnostics
- 2.4: Demonstration of the Whole Building Diagnostician
- 2.5: Pattern Recognition Based Fault Detection and Diagnostics
- 2.6: Enhancement of the Whole Building Diagnostician
- 2.7: Enabling Tools

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-2.1: Fault Detection & Diagnostics for Rooftop Air-conditioners

- Objectives
  - Extend FDD system to families of RTU
  - Develop methods to detect simultaneous faults
  - Assess the economic benefits of applying the FDD system in California
- Approach: Lab analysis & field data collection from 10 sites

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-2.1 Technical Outcomes

- FDD system can be applied to RTU families
- Significant improvements were made in methods for detecting single faults
- Multiple-fault FDD is feasible for RTUs with fixed orifice and thermal expansion valves

P-2.1 Conclusions

- Net savings per unit: $4,000 to $10,000 (over 10-yr life)
- The FDD methods apply to packaged AC, which supplies about 54% of building mechanical cooling in California
- Estimated Energy Impact: 100 GWh/yr by 2015
  - Assuming 14% savings using FDD
  - Assuming FDD available on 26% of all new units installed between 2005 and 2015

pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-2.2 Equipment Scheduling and Cycling

- Objectives: Develop and demonstrate fully automated FDD for HVAC using the Non-Intrusive Load Monitor technology
  - Automate detection of on/off events
    - constant power/constant speed loads
    - variable speed/variable power loads
    - variable-power/constant-speed loads
  - Investigate & automate fault detection methods
- Approach: Lab & Field Tests

P-2.2 Technical Outcomes

- Extended NILM to automatically detect scheduling and cycling events for
  - constant power/constant speed loads

    (fans, pumps, & reciprocal chillers)
  - variable speed/variable power loads

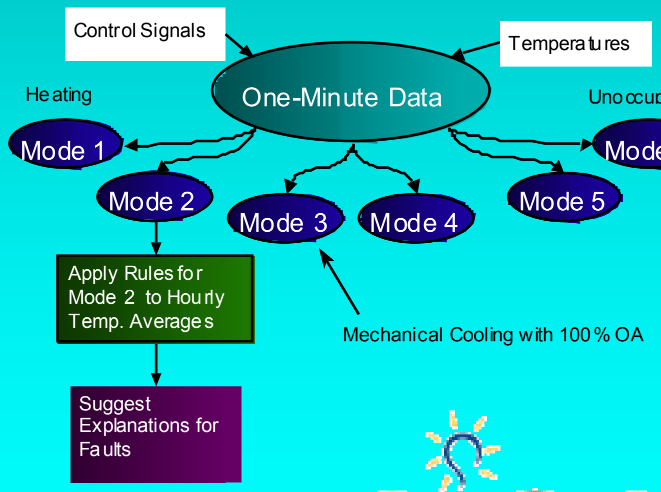
    (VSD fans & pumps)
- Good progress made on automatic detection for variable-power/constant-speed loads (chillers)
- Detected a number of faults that are difficult to detect with non-electrical measurements.

P-2.2 Conclusions

- Information generated by application of NILM technology will be less expensive than that created using traditional power submetering and acoustic/vibration monitoring.
- Predicted cost ~ $200/unit, made in 10's of 1,000's
- Estimated Energy Impact: 219 GWh/yr
  - Assuming 3125 kWh/yr savings from each installation
  - Assuming 70,000 installations over 10 years

P-2.3 AHU & VAV Box Diagnostics

- Objectives
  - Detect 7 common mechanical faults & control errors in AHUs and VAV boxes
    - AHU Performance Assessment Rules (APAR)
    - VAV box Performance Assessment Control Charts (VPACC)
  - Rely only on sensor data & control signals commonly available in BAS
  - Can be embedded in commercial building unit controllers
- Approach: Lab testing & verification using field data



P-2.3 Technical Outcomes

- Lab testing: Faults correctly detected included stuck or leaking dampers and control valves, sensor drift, and improper control sequencing.
- Field data testing: an office building, a restaurant, and community college and university campuses, featuring constant- and variable-air-volume systems.
- APAR and VPACC rule sets were embedded in controllers from three manufacturers using their respective native programming languages.

P-2.3 Conclusions

- **APAR & VPACC can be added to controllers at little or no added direct cost**
- Four manufacturers are working with NIST
- Estimated Energy Impact: 393 GWh/yr
  - Applied to 50% of floor space in hospitals, colleges, and large office buildings
  - Assuming 50% fault correction rate
  - Assuming savings of 0.5 kWh/sf

P-2.4 Whole Building Diagnostician Demonstration

- **Objectives:**
  - Prove WBD efficacy
  - Test user interactions
  - Develop case studies of the impacts
  - OAE/WBD user feedback to guide development of the other tools
- **Approach:** Three demo types
  - Single building operator
  - Multi-building operator (campus)
  - HVAC services provider

P-2.4 Technical Outcomes

- Off-line operation 100% successful
- On-line operation had data acquisition challenges
- One of three operators took action on reported faults
- The annualized cost of single faults detected ranged from $500 to $15,000
- No case studies developed
- Good feedback from operators

P-2.4 Conclusions

- Savings potential for FDD on air handlers is large
- Savings only happen when problems are fixed
- The time and cost of diagnostic-tool installation is a significant component to implementing diagnostic technologies
- Estimated Energy Impact:
  - Central plant based HVAC: 393 GWh/yr
  - Packaged HVAC: 95 GWh/yr
  - Assuming 0.5 kWh/sf-yr savings

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

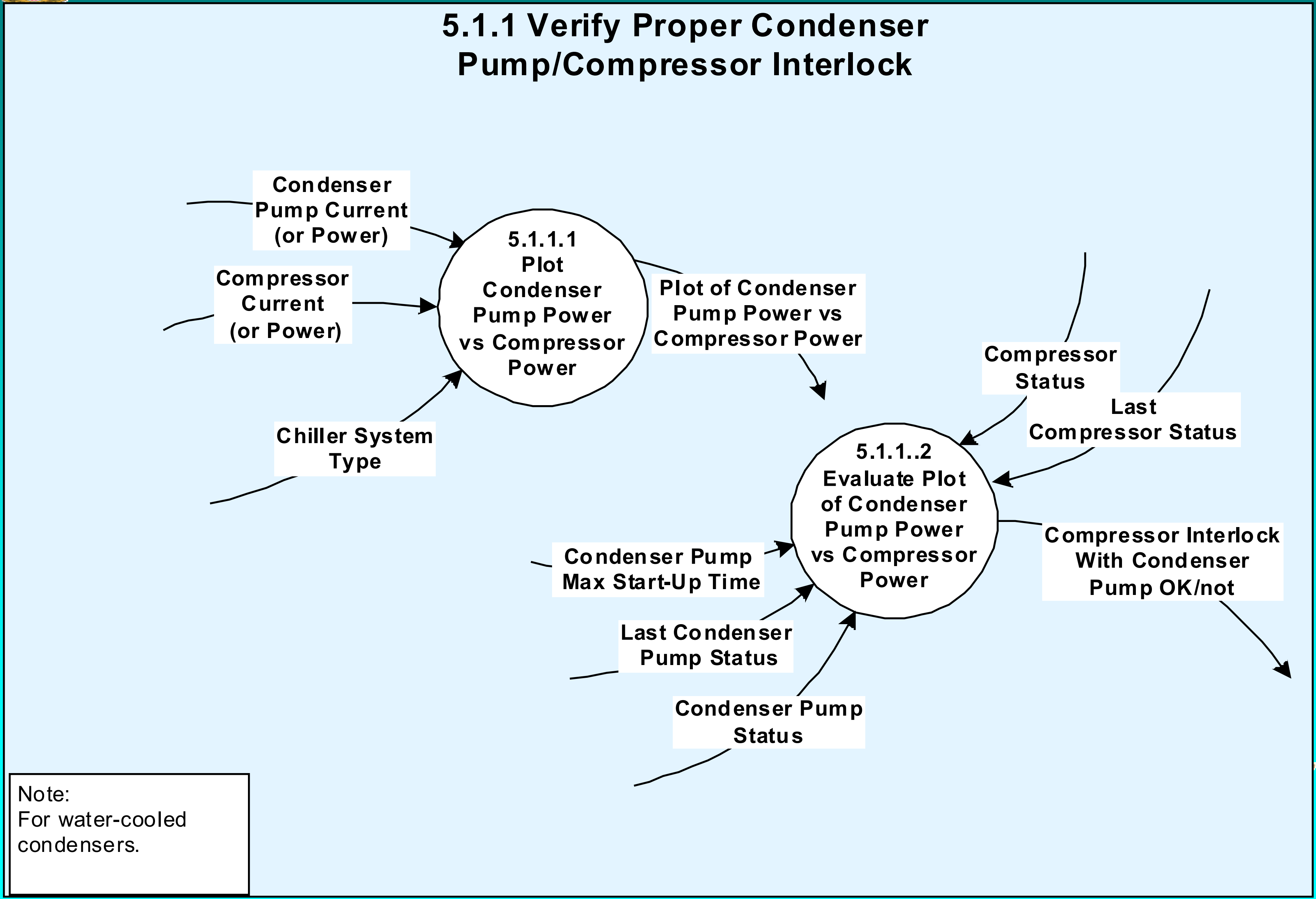
P-2.5 Pattern Recognition Diagnostics

- Objective: Develop pattern-recognition techniques that automate FDD based on visual comparison of plots of good and bad system performance
- Approach: Automate engineering methods and diagnostic plots in AEC's ENFORMA HVAC Analyzer for chillers, boilers, pumps, and cooling towers

P-2.5 Technical Outcomes

- Selected a set of rule-based methods for FDD
  - Based on how an expert analyzes the plots of data for chillers and boilers
- Implemented a small set of FDD algorithms in spreadsheet with GUI to test and illustrate the concept of automation
- Tested using data collected from buildings in pre-program projects
- A fully documented software specification was produced

P-2.5 Software Spec Example



P-2.5 Conclusions

- **The diagnostic approach is suitable for periodic or continuous monitoring**
  - existing building control systems
  - component controllers or
  - central service center.

- Estimated Energy Impacts: 123 GWh/yr
  - Assuming applications in 50% of existing floor area for hospitals, colleges, and large offices

P-2.6 Whole Building Diagnostician Enhancements

- Objectives
  - Modify the Whole Building Energy (WBE) module to allow use of any two non-schedule variables and to optionally display hourly results for peak loads.
  - Add peer-group comparison that compares current building consumption in quasi-real time against that of a set of similar participating buildings in the same vicinity or climate zone.

P-2.6 Technical Outcomes

- Added the capability to use any five independent variables instead of two
- Hourly plots available for reviewing peak demand patterns
- Added a peer group comparison module in a recent release

P-2.6 Conclusions

- The enhanced features of the WBD/WBE will promote wider use by building operators.
- The WBD documentation provides instructions for creating files for batch processing by the WBD, which removes most of the difficulties associated with data collection.
- Estimated Energy Impact: 239 GWh/yr annually
  - Assuming 29% of commercial buildings have EMS
  - Assuming 20% of those with EMS install WBD
  - Assuming 5% savings due to WBD

P-2.7 Enabling Tools

- Objectives
  - Enhance the VCBT and FDD Test Shell tools by embedding typical faults in the VCBT and developing communication tools needed for demonstrating diagnostic tools in real buildings.
  - Conduct blind tests of the Whole Building Diagnostician to test its effectiveness, and to test the communication tools within the VCBT/FDD Test Shell framework.

P-2.7 Technical Outcomes

- Typical HVAC system and component faults were embedded in the VCBT simulation engine and the FDD Test Shell was interfaced to the VCBT.
- Data acquisition capability was added to the FDD Test Shell
  - off-line testing completed with data from real buildings
  - on-line testing was not completed
- Analyzed WBD/OAE in the blind tests for low, normal, and high sensitivity
- In 3 of 4 blind trials on the WBD/WBE, faults were correctly identified

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-2.7 Conclusions

- The improvements made under this project to the VCBT and FDD Test Shell enabled testing of WBD and demonstrated the feasibility of laboratory testing of FDD tools
- The VCBT and FDD Test Shell is available to manufacturers and other interested parties as a platform for product development and testing.
- <u>Benefit to California</u>: National level tools benefit California because the makers of building controls sell their products into the national market.

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

Element 3:
Advanced Load Management & Control

- 3.1: Demand-Controlled Ventilation Assessment
- 3.2: Night Ventilation & Building Thermal Mass
- 3.3: Smart Load Control and Grid-Friendly Appliances
- 3.4: Extending BACnet for Lighting and Utility Interface
- 3.5: Aggregated Load Shedding

P-3.1 Demand Controlled Ventilation (DCV) Assessment

- Objectives
  - Assess potential energy & cost savings for CO_2-based DCV strategies in California for small commercial and institutional buildings
  - Identify key drivers determining the cost-effectiveness of DCV
  - Provide design requirements and guidance to deploy DCV strategies
- Approach: simulations validated with field testing at 10 sites

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-3.1 Technical Outcomes

- Literature review: a fairly wide consensus on the best applications for CO_2 control
- Developed a stand-alone ventilation strategy assessment tool (VSAT)
  - prototypical building spaces: classroom, auditorium, library, office, retail, restaurant
  - ventilation strategies: economizer, DCV, enthalpy energy exchanger, heat pump energy recovery
  - new and retrofit
  - all California climate zones

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

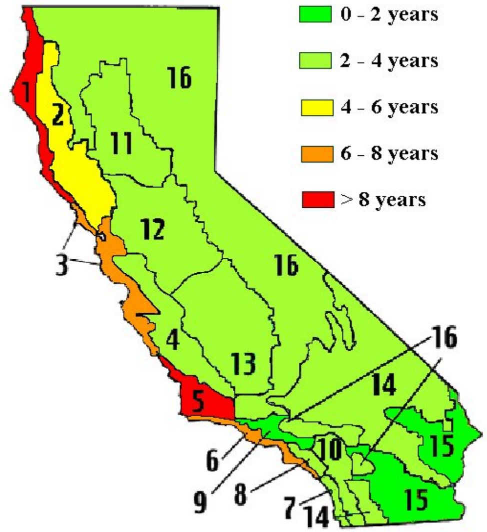
P-3.1 Technical Outcomes

- Indoor air contaminant simulations
  - Simulated CO_2 and VOC concentrations in six space types for seven ventilation control strategies in four California CZ
  - CO_2 control cases had higher concentrations than the reference cases based on Standard 62-2001 and proposed addendum 62n
  - Average & max VOC concentrations were heavily influenced by concentration build-up in unoccupied hours
  - spaces with more variable occupancy had significant energy savings in all the climates studied
  - Predicted annual energy savings for CO2 control ranged from 10 % to 80 % depending on the space type, climate and ventilation strategy

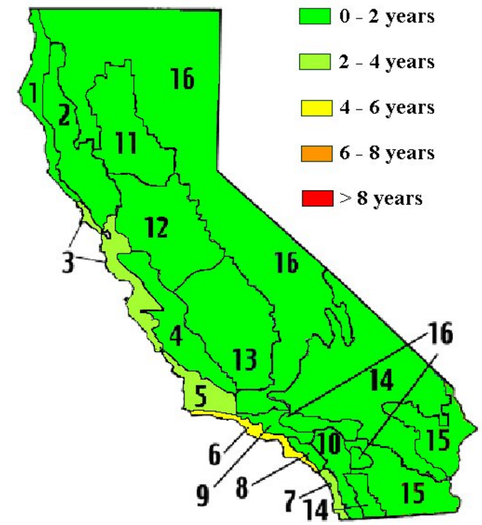
P-3.1 Technical Outcomes

- Field Assessment of DCV: Pairs of coastal and inland sites
  - 4 McDonald's play rooms
  - 4 modular school rooms
  - 2 Walgreens retail stores
- Cooling and heating season performance of DCV at the QSR play rooms and the modular schools was evaluated for Economizer-Only and DCV+Econ
  - Monitored performance was better for play rooms
  - Modular schools had flat occupancy profile and DCV provided little benefit
  - Annual air conditioning cost savings ranged from 23% for inland and 6% for coastal QSR play rooms

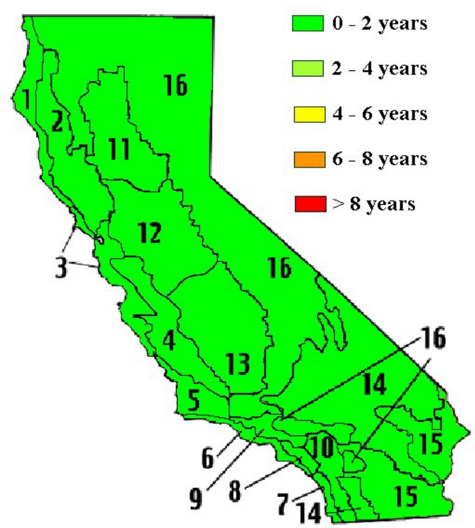
Predicted Payback Periods for Retrofit Construction of DCV + Econ



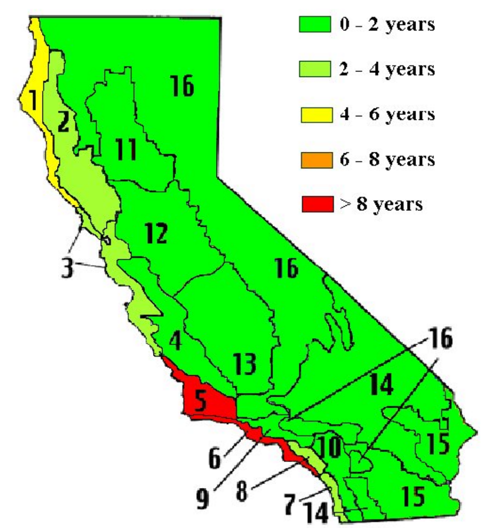
Office



Restaurant



Retail



Classroom

P-3.1 Conclusions

- Retail, office, and certain restaurant spaces are good targets for DCV in the inland climate zones
- DCV + Econ gave the largest cost savings
- Estimated Energy Impact: 626 GWh & 373 MW
  - Packaged HVAC in offices, retail, restaurant, schools
  - Target 626 million sf of 3,109 million sf
  - Assumed 2-yr payback & $0.15/kWh avg energy cost

P-3.2 Night Ventilation & Building Thermal Mass

Objective

- Develop, implement, and demonstrate a control strategy for using night-time ventilation and building mass to reduce cooling requirements and peak cooling demand while ensuring adequate thermal comfort.

Approach

- Field test algorithm
- Use VSAT for screening
- Improve algorithm based on field tests

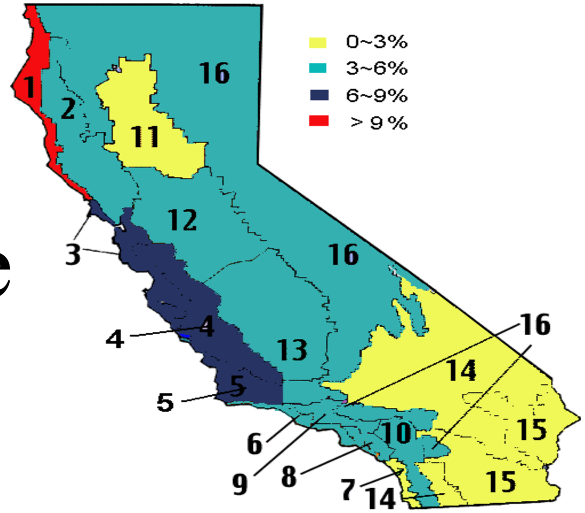
P-3.2 Technical Outcomes

- VSAT used to evaluate:
  - small office building
    sit-down restaurant
    retail store
    school auditorium
    school class wing
    school gymnasium
    school library
- Predicted savings:
  - kWh varied between 0 and 8%
  - kW varied between 0 and 28%
  - $ varied between 0 to 17%

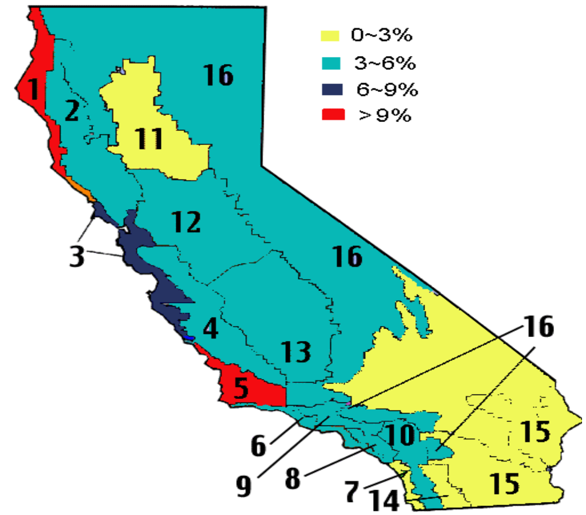
P-3.2 Technical Outcomes

- A simplified version of the control algorithm operated correctly within two field sites
  - Debugged at a small office building
  - Successful field trial at retail store with 5 HVAC units
    - Coordinated control among HVAC units is required

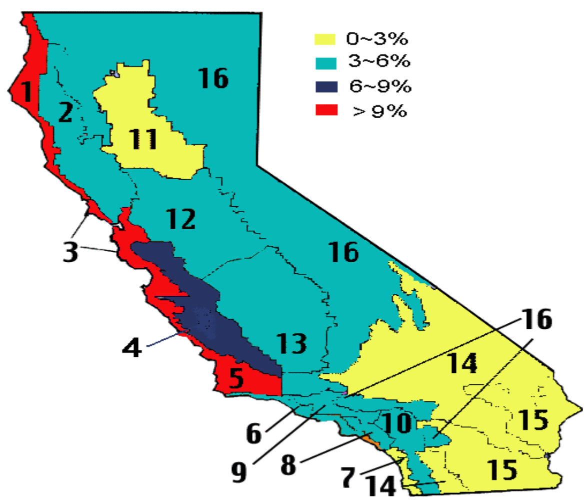
Relative savings by climate zone for Night Ventilation Pre-cooling



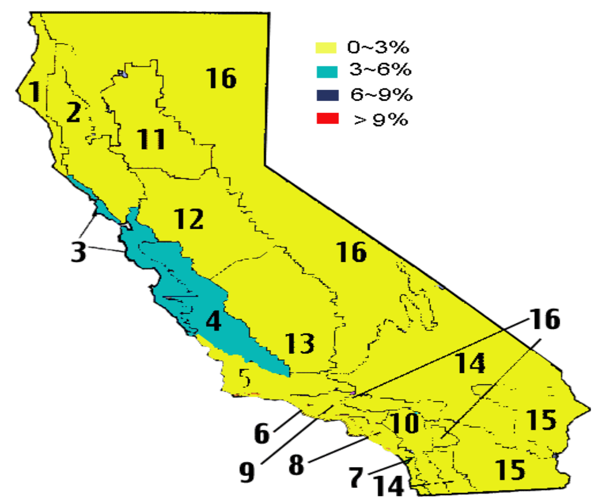
Office



Retail



School Class Wing



Restaurant

P-3.2 Conclusions

- Greatest % savings occur in coastal climates with relatively mild ambient temperatures
  - savings are also significant in hot inland climates having larger total loads
  - savings are less for the restaurant due to less thermal mass, longer occupancy schedule, & greater ventilation requirements
  - efficient, variable-speed fan motors would increase savings
- Estimated Energy Impact: 103 GWh & 61 MW
  - used in 25% of space w/ packaged HVAC
  - assuming 5% savings in cooling energy

pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-3.3 Smart Load Control & Grid Friendly Appliances

- **Objective**

  Develop smart load controls for residential and commercial appliances (e.g., refrigerators, electric hot water heaters, and other appliances) that enhance the reliability of the power system in California, and support cold load pickup after power outages.

- **Approach**
  - lab testing of algorithms using power data from high stress periods
  - developing prototype hardware

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-3.3 Technical Outcomes

- Developed two load controller prototypes based on detecting under-frequency events and based on spectral analysis
- Based on simulations of the western US power grid, tested a set of hypotheses that distinct signatures could be detected in the grid frequency during transitions from a low-stress to a high-stress condition
- Distinct high-stress pre-cursors could not be identified

P-3.3 Conclusions

- A definitive low stress state could not be defined due to changes in the topology of the network from:
  - randomness and magnitude of constantly changing loads
  - adjustments by generators to meet the demand
  - randomness of the unplanned outages
- Estimated Energy Impact

  The objective of this project was not to save electric energy or to reduce electric peak demand, but to enhance power grid reliability in California and to prevent power outages.

P-3.4 Extending BACnet for Lighting and Utility Interface

- Objectives
  - Enhancements to ASHRAE Standard 135 (BACnet) to support
    - lighting control services
    - communications between a building and the utility
- Approach
  - Develop consensus based proposals within the ASHRAE SSPC 135 and industry organizations

P-3.4 Technical Outcomes

- Two working groups within ASHRAE SSPC 135 were created:
  - Lighting Applications Work Group (LA-WG)
    - National Electrical Manufacturers Association (NEMA)
    - Illuminating Engineering Society of North America (IESNA)
  - Utilities Interface Working Group (UI-WG)
    - Electric Power Research Institute (EPRI)
    - Institute of Electrical Installation Engineers of Japan (IEIEJ)

P-3.4 Technical Outcomes

- Two Lighting Control objects are expected to be approved as amendments to the BACnet standard before the end of 2003
  - Multiplexer Object
  - Lighting Control (DALI) Object
- Two Utility Interface objects recently went through a public review
  - Accumulator Object
  - Pulse Converter Object
- Three more objects in proposal stage

P-3.4 Conclusions

- Integrating lighting control & utility meter interfacing into BACnet will provide a non-proprietary, standard communication framework for BAS.
  - It will reduce the costs of supporting multiple standards within controls products, making it less expensive to provide controls in all commercial buildings
  - Controls in more buildings will reduce energy use and improve indoor environments
- Estimated Energy Impact: 896 GWh &102 MW
  - Assuming 25% of commercial buildings
  - Assuming 10% lighting savings

P-3.5 Aggregated Load Shedding

- Objectives
  - Identify opportunities to better control electrical loads in groups of buildings by aggregating load shapes
  - Evaluate the potential impact of aggregated load control by coordinating control actions
  - Identify needed developments in control and communication systems
- Approach
  - Simulations & field experiments

P-3.5 Aggregated Load Shedding

P-3.5 Technical Outcomes

- Load shedding potential is a function of three building/ occupancy characteristics and one control parameter.
  - magnitude of loads (primarily lighting and plug loads) that can be shut off *at the time that load curtailment is called for*
  - cooling plant efficiency (reduction in HVAC plant power that can be realized per kW reduction in lighting and plug loads); and
  - potential for thermal storage within the conditioned space

P-3.5 Technical Outcomes

- Aggregated-load shedding for groups of two or three buildings is effective in reducing peak demand and overall power consumption.
  - Thermostats (two and three building cases):
    - peak load reduction of 2 – 14%
    - cost reduction of 2 – 12%
  - fan-based and chiller-based night cooling (2 bldgs)
    - peak load reduction of 27%
    - cost reduction of 20%

P-3.5 Technical Outcomes

- Field Experiments
  - Short duration (one hour) load curtailment experiments showed that about 330 kVA could be saved in the ECC building and about 250 kVA in the ISD building.
  - Night pre-cooling experiments demonstrated that chiller and pump power could be reduced by 20% for an entire day by pre-cooling the building the night before.

P-3.5 Conclusions

- Night pre-cooling may be viable long-term option to consistently reduce electric energy use and demand
- Short-term load curtailment by shutting down chillers can provide an hour of load reduction
  - without adverse comfort impact and
  - without exceptional demand increases upon release from curtailment.
- Aggregated load curtailment by an operator of multiple buildings on a common meter is feasible
- Estimated Energy Impacts:338 GWh/yr and 167 MW
  - Applied to 50% of hospitals & colleges
  - Assuming 5% kWh & 10% kW savings

Element 4: Alternative Cooling Technologies & Strategies

- 4.1: Modular High-Efficiency Gas Absorption Chiller Demonstration
- 4.2: Assessment and Field Testing of Ventilation Recovery Heat Pumps
- 4.3: Residential High Velocity HVAC Distribution System Demonstration
- 4.4: Design Methods and Guidelines for Natural Ventilation in California

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-4.1 Modular High-Efficiency Gas Absorption Heat Pumps

- **Objectives**
- Test hypothesis: small modular gas-fired absorption chillers, when staged to serve 15 to 25 ton loads, will have a net energy efficiency equal to, or greater than, conventional electric motor-driven chillers
- **Approach**
  - Demonstrate a control system linking modular 5-ton gas-fired absorption chillers to create typical 15- to 25-ton packages suitable for small and medium commercial and institutional buildings
  - Develop a modular 5-ton absorption heat pump system and demonstrate it using a control system linking units to serve 15- to 25-ton loads.

P-4.1 Technical Outcomes

- Development of the GAX heat pump was cancelled at the end of the first year due to changed market conditions
- A demonstration site for the linked chiller concept was identified
- The linked GAX chiller demonstration was cancelled after determining that the monitored loads did not meet the experimental design requirements

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-4.1 Conclusions

- Based on subsequent research at ORNL, gas heat pump technology appears to be better suited for cold climates

P-4.2 Heat Pump Ventilation Recovery Assessment

- Objectives
  - Identify the most promising applications of ventilation recovery heat pumps for small commercial buildings in California.
  - Demonstrate the technology in a favorable application and document its performance.
- Approach
  - Simulations and field testing

P-4.2 Technical Outcomes

- The HPHR system functioned properly during field and laboratory testing.
- HPHR cooling COP must be high enough to overcome:
  - additional cycling losses from the primary air conditioner compressor
  - additional fan power associated with the exhaust and/or ventilation fan
  - additional cooling requirements due to a higher latent removal
  - a lower operating COP for the primary air conditioner compressor because of a colder mixed air temperature.
- HPHR is an alternative to an economizer and so economizer savings are lost

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-4.2 Conclusions

- The HPHR system did not provide positive cost savings for most building type/climate combinations investigated
- The HPHR system should not be considered for use in California, except in perhaps certain mountain areas with larger heating loads

P-4.3 Residential Radiant Cooling Assessment

- **Objectives**

  Compare the electrical energy use and demand for three cooling modes and two heating modes to assess which mode is the best energy alternative

- **Approach**

  Extensive monitoring of a residence with three cooling and two heating distribution systems:

  - conventional forced air (cooling & heating)
  - hydronic tubing embedded in slab on grade (cooling & heating)
  - forced air night ventilation
    (cooling only, 100% outside air)

P-4.3 Technical Outcomes

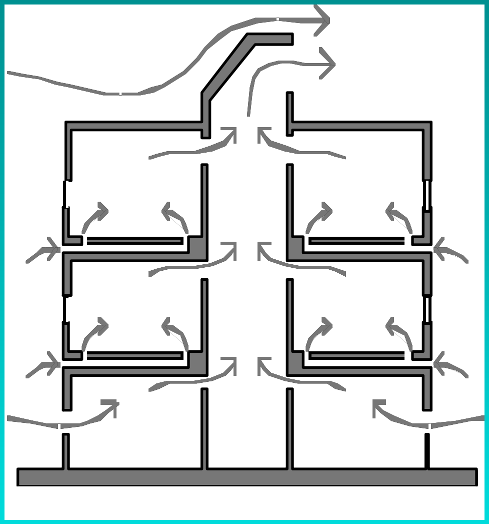
- Mode 1: conventional forced air
- Mode 2: conventional forced air + hydronic cooling between 4 AM and 8 AM
- Mode 3: conventional forced air + hydronic cooling between 4 AM and 8 AM + night 100% OA cooling

Mode	Avg Daily kWh	Peak Demand	Time of Peak kW	% Energy Used midnight to 11 AM	Avg OAT (F)	# Test Days
1	11.0	1.4	7:15 PM	14%	77.7	29
2	4.6	1.1	6:45 PM	13%	75.4	30
3	9.7	1.1	4:15 AM	72%	75.8	26

P-4.3 Conclusions

- Mode 2 reduced average daily energy use by more than 50% compared to Mode 1
  - Mode 2 OAT was 2 °F cooler than Mode 1
- Mode 3 used almost as much average daily kWh as Mode 1, but Mode 3 used 72% during off peak hours (midnight to 11 AM)
- There was no significant difference in conventional forced air heating and radiant hydronic heating modes
- Estimated Energy Impact: 0.6 GWh and 0.7 MW
  New construction 230,000 homes/yr
  1 - 2% use radiant hydronic & 20% savings

P-4.4 Design Methods & Guidelines for Natural Ventilation



➢ Objectives

- Develop natural ventilation strategies for cooling load reduction in small commercial buildings in California.
- Develop natural ventilation design methods, construction techniques, and strategies that address non-energy benefits, such as occupant comfort and indoor air quality.
- Develop natural ventilation software tools for design to improve building energy efficiency and lower the cost of building design, construction, and operation.

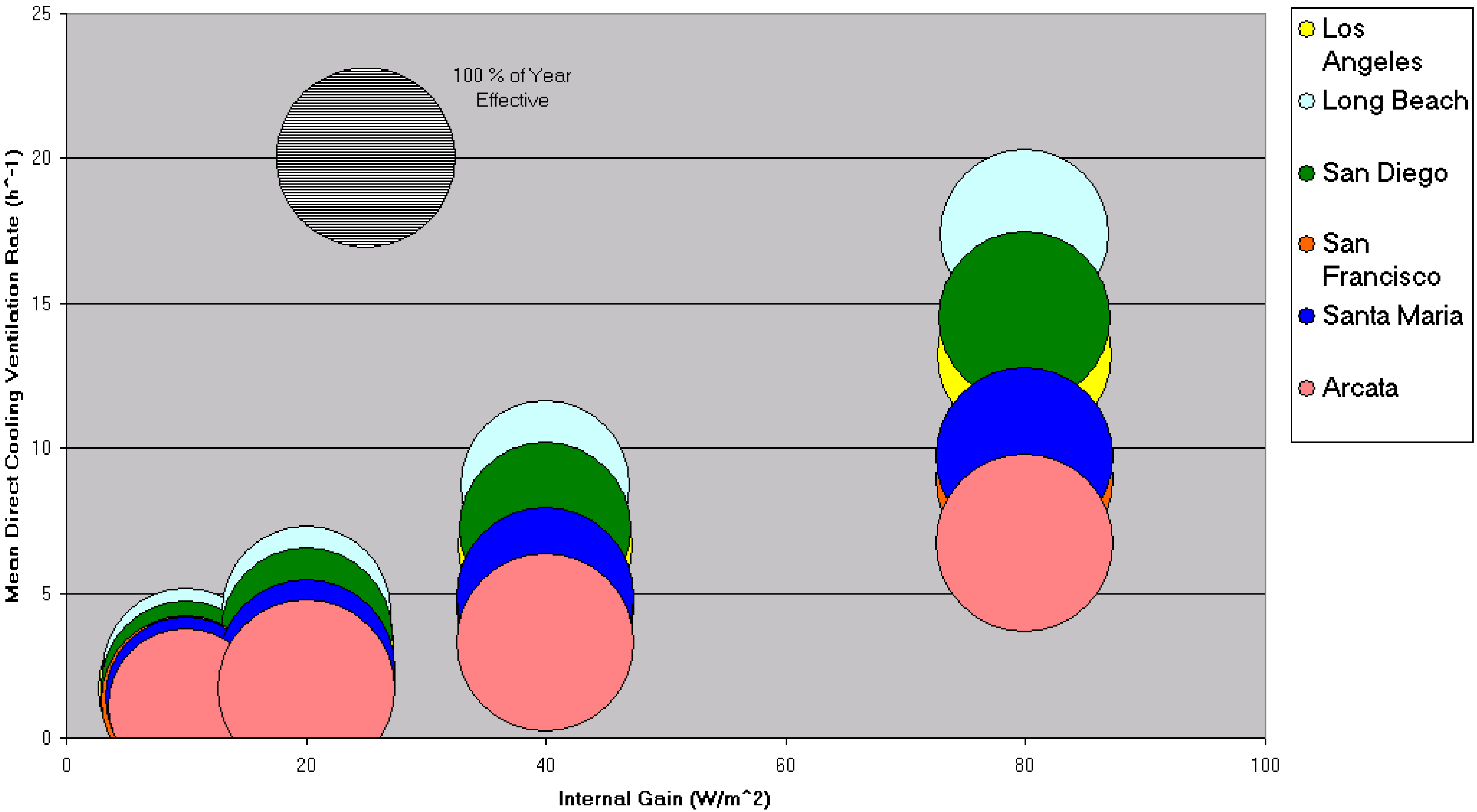
➢ Approach

Simulations and software development

P-4.4 Technical Outcomes

- A new ventilative cooling metric was used to demonstrate that the coastal climates of California are potentially very well suited to natural ventilation
- An eight-step design guide for natural ventilation applications was developed
- Natural ventilation design and analysis software, called LoopDA (for Loop Design and Analysis), was developed to aid in sizing and placement of natural ventilation devices

Required Natural Ventilation Rate vs. Internal Load



P-4.4 Conclusions

- Five important considerations specific to the application of natural ventilation to commercial buildings in California are climate suitability, ambient air quality, internal loads, thermal mass, and relevant codes and standards
- The coastal climates in California are very well suited for natural ventilation. The inland climates are not, but night cooling and hybrid ventilation systems would work well provided design parameters are suitable.
- Estimated Energy Impact: 13.6 GWh/yr
  1% adoption in new construction thru 2015

Element 5: Alternative Construction Techniques & Technology

- P-5.1 Building Integrated Photovoltaics

P-5.1 Building Integrated Photovoltaics

- Objectives
  - To develop a validated design algorithm to predict the energy production of building-integrated photovoltaic modules.
  - To use the resulting model to predict the energy savings possible by using curtain-wall photovoltaic products that are integrated for buildings in high growth areas of California.
- Approach: Panel performance monitoring & analysis, and simulations

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-5.1 Technical Outcomes

- The highest overall conversion efficiency (sunrise to sunset) was achieved using single-crystalline cell panels, but less efficient and less expensive cell technologies can have faster paybacks.
- The improved algorithms resulting from this research were incorporated into the DOE-2.2 building energy simulation program.
- Self-shading, or shading from other buildings or vegetation will reduce the savings, in some cases substantially, due to BIPV circuitry.
- Insulation behind PV panels degrades power production slightly in three out of the four cell technologies tested.
- A vertical south-facing BIPV panel has a small effect on building or system summer peak demand.

P-5.1 Conclusions

- Vertically-mounted BIPV energy production and demand reductions differed by cell technology, but were insensitive to climate for two coastal and two inland locations, so the technology can be used throughout California.
- Using a PG&E small commercial electric rate, simple payback periods for all locations ranged between 10 to 45 years depending on PV technology, and including utility or government rebates or tax credits.
- Roof-mounted and parking structure-mounted BIPV have better electric generation and demand reduction profiles, but they are not as visible to the public as façade-mounted BIPV.
- Estimated Energy Impact: 11 GWh/yr by 2015

  Assuming 2.4 million square feet of new commercial construction between Years 2000 and 2015.

  Assuming that 2% of new construction includes façade-mounted BIPV and annual generation of 6 kWh/sf.

Element 6: Impact Assessment

- P-6.6 Development of an Impact Assessment Framework

P-6.6 Development of an Impact Assessment Framework

- Objective

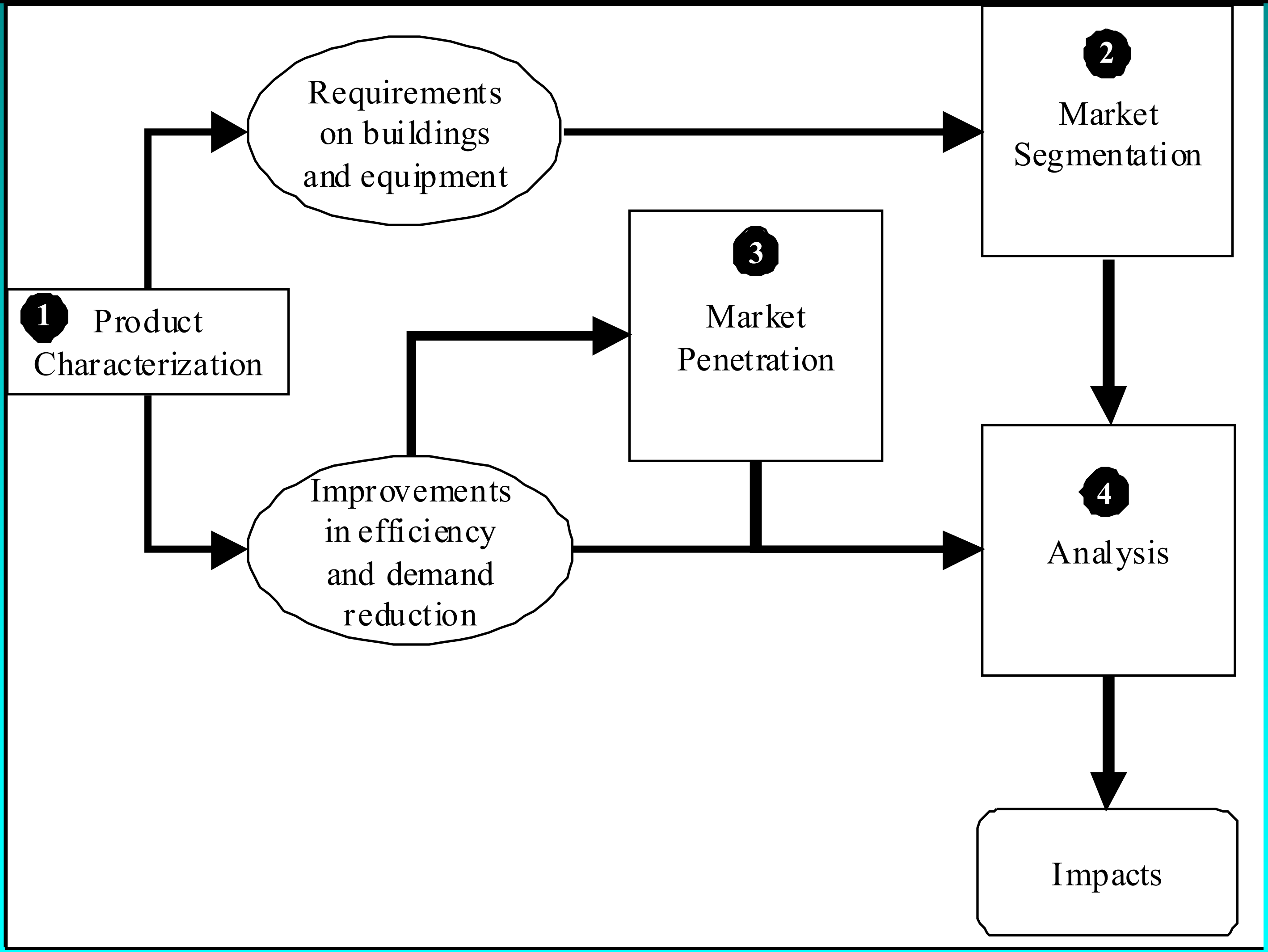
  Develop and demonstrate an impact assessment framework that:

  - identifies explicitly the assumptions and inputs to the assessment process
  - evaluates technologies for energy savings and electric peak demand reduction potential.

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

P-6.6 Technical Outcomes

- The assessment framework developed for the commercial building sector is composed of four components
  - Product Characterization
  - Market Segmentation
  - Market Penetration
  - Analysis of Impacts
- The framework was exercised in a pair of examples to illustrate some of its behavior and to demonstrate how Commission staff may use the framework in the future.



Requirements on buildings and equipment
2
Market Segmentation
3
Market Penetration
1
Product Characterization
Improvements in efficiency and demand reduction
4
Analysis
Impacts

P-6.6 Conclusions

- Product description and market segmentation are very important for defining market potential.
- Market penetration estimates have a wide range of uncertainty, even with the benefit of a well-defined assessment methodology.
- The predicted outcomes using the market penetration models are highly sensitive to initial estimates of market share.

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

Program Summary

- Program Total Estimated Savings = 3,550 GWh/yr
  3.9% of Year 2000 Statewide Commercial Load (91,771 GWh/yr)
- This is equivalent to about 400 MW base load
- Program Cost = $5,422,000
- Program Cost Effectiveness: $13.37/kW, $0.0015/kWh
  - Assuming no overlap in project savings
  - Not including implementation costs

Where to Get More Information

- Commission Web Site: http://www.energy.ca.gov/research/PIER
- Chris Scruton (916) 653-0948
  - E-mail: cscruton@energy.state.ca.us
- AEC Web Site: http://www.archenergy.com/cec-eeb
- Vern Smith (303) 444-4149
- E-mail: vsmith@archenergy.com

PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"